S207 The Physical World

Are you ready for S207?

Contents

If, after working through these notes, you are still unsure about whether S207 is the right course for you, we advise you to seek further help and advice either from a Regional Adviser or from a Science Staff Tutor at your Regional Centre.

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5.2

1 Introduction

This document is designed to help you diagnose your ability to make a successful start on the Level 2 Science course S207 *The Physical World*. You should read it in conjunction with the information provided in the *Course Choice Part 2*.

If you intend to study S207, it is essential that you establish whether your background and experience give you a sound basis on which to tackle the course so that you will have the best possible chance of completing it successfully.

Read through the following notes carefully and work through the self-assessment questions (SAQs). This is a useful exercise for all prospective students of this course, even for those who have already studied other Open University Science courses. Working through these diagnostic notes will serve as a reminder of some of the knowledge and skills which it is assumed that you will bring with you, either from Level 1 Science courses or from other prior study. If you find that you can answer most of the questions in these notes correctly, then it is likely that you are adequately prepared to take on S207.

However, if you find that you have substantial difficulties with more than two or three questions in Section 3 or if any of the maths topics (with the possible exception of Section 3.5) are totally new to you, then you should seriously consider first undertaking some preparatory study, such as a Level 1 Mathematics course. The short course, S151 *Maths for Science* would be useful preparation, and we strongly recommend that you take this 10-point course prior to starting S207 if you have any difficulty with the mathematics questions below. S151 has four course start dates per year, enabling you to study it prior to S207.

Our research shows that students studying other courses (except for SXR207, the associated residential school course) concurrently with S207 typically find the workload too high and have a lower chance of successfully completing their studies of S207. If, despite this word of caution, you intend to study another course alongside S207, please do seek advice from a Science Staff Tutor at your regional centre.

2 Suggested prior study

You do not require any prior *subject-oriented* knowledge to study the material in S207 — all topics covered are introduced and taught within the course itself. What you do need, however, is a basic familiarity with the scientific way of thinking, arguing and communicating. Before studying S207 it would help to have studied and passed one of the Level 1 Science courses (S102, S103 or S104) or their equivalents.

Whilst there are no *formal* mathematics prerequisites for S207, you do need some basic skills (see below) and students who have undertaken previous mathematics study (e.g. MST121, MU120, S151) have a much stronger chance of successfully completing S207. If you have not undertaken such study, then you should work carefully through these notes and follow the advice given in the last paragraph of the Introduction.

3 Mathematical skills

At a minimum, in order to start on S207, you need to be familiar with basic algebra manipulations, elementary geometry and trigonometry; you need to be able to plot and interpret graphs and to use a scientific calculator. Beyond this, all the formal mathematics that you will need is developed within the course. However, much of the mathematics in S207 is introduced quite quickly and mainly at the beginning of the course, so some prior knowledge of the topics detailed below is essential. You should put aside some time to work through the S207 *Maths Handbook* before the start date of S207.

The following sections outline the most important mathematical concepts developed in S207, with references to where these concepts are taught in S151 (i.e. *all* references are to Chapters in S151, *not* S207).

3.1 Numbers and calculations

The physics in S207 involves the use of very large and very small numbers. These are best expressed in scientific notation (the speed of light, for example, can be written as $3.0 \times 10^8\ \mathrm{m\,s^{-1}}$) and this convention is used throughout the course S151: Chapters 1 and 2). Note that in all your calculations, you should also use the appropriate units (such as $\mathrm{m\,s^{-1}}$ for velocity or $\mathrm{N\,m^{-2}}$ for pressure) when expressing your result, rather than giving only a number.

SAQ 1

Express the following numbers in scientific notation:

(a)	200 000 000	(b)	95×10^5	(c) 1/1000 000
(d)	21 000	(e)	0.63×10^4	(f) 0.000 33 ■

You are expected to perform calculations using a simple scientific calculator, expressing the result to an appropriate number of significant figures.

SAQ 2

Do the following calculations and express your answers in scientific notation, to the appropriate number of significant figures, and in the correct units:

(a) 0.63 m + 2.218 m

(b) 8.4 kg – 3.02 kg

(c) (2.394×10^3) m $\times$ (5.60×10^4) m

(d) (7.642×10^3) kg / 2.82 $\mathrm{m^3}$ ■

3.2 Algebra

Simple algebraic equations are used throughout S207. You should know how to rearrange equations to make a desired quantity the subject (S151: Chapter 4).

SAQ 3

If a car accelerates steadily along a straight road from an initial speed u up to a final speed v in time t, then the magnitude of its acceleration is $a = (v - u)/t$. Rearrange this equation to make the final speed v the subject of the equation (i.e. you should rearrange this equation into one that starts $v = \ldots$). ■

Sometimes you will need to combine two expressions to make a third.

SAQ 4

Suppose that $x = 2z^2/a$ and $a = 4zr$. Combine these two equations to give an equation for x that does not involve a. ■

You will also need to know how to take squares (e.g. $2^2 = 4$) and square roots (e.g. $\sqrt{2} = 1.414$), using a calculator if necessary.

SAQ 5

Use your calculator to work out the squares of 3.2, 17.4, 8.3 and 0.5, and the square roots of 80, 111, 1015.3 and 0.5. Express the answers to the same number of significant figures as in the original number. ■

You should be able to combine powers of quantities in both numerical and algebraic expressions.

SAQ 6

Simplify the following expressions:

(a) $\dfrac{x^5 \times x^2}{x^3}$

(b) $10^{-7} \times 10^5$

(c) $y^{-3} \times (y^4/y^2)$

(d) $z^{1/2} \times z^2$ ■

At several points in S207 you will be forming an algebraic equation from a proportionality by using a constant of proportionality.

SAQ 7

If y is proportional to x^2 ($y \propto x^2$), write down a simple equation relating y to x using a constant of proportionality, k. What is the equation if y is inversely proportional to x^2? ■

3.3 Trigonometry

Simple trigonometry (S151: Chapter 6), requiring the use of sines, cosines and Pythagoras' theorem, is used in S207. You should be able to solve problems involving triangles.

SAQ 8

Use your calculator to work out the following, expressing your answers to two significant figures: (a) sin 60°; (b) cos 60°; (c) cos 30°; (d) cos 145°. ■

SAQ 9

For each of the triangles shown in Figure 1 below, calculate the value of the quantities indicated by a question mark (either an angle or the length of a side). ■

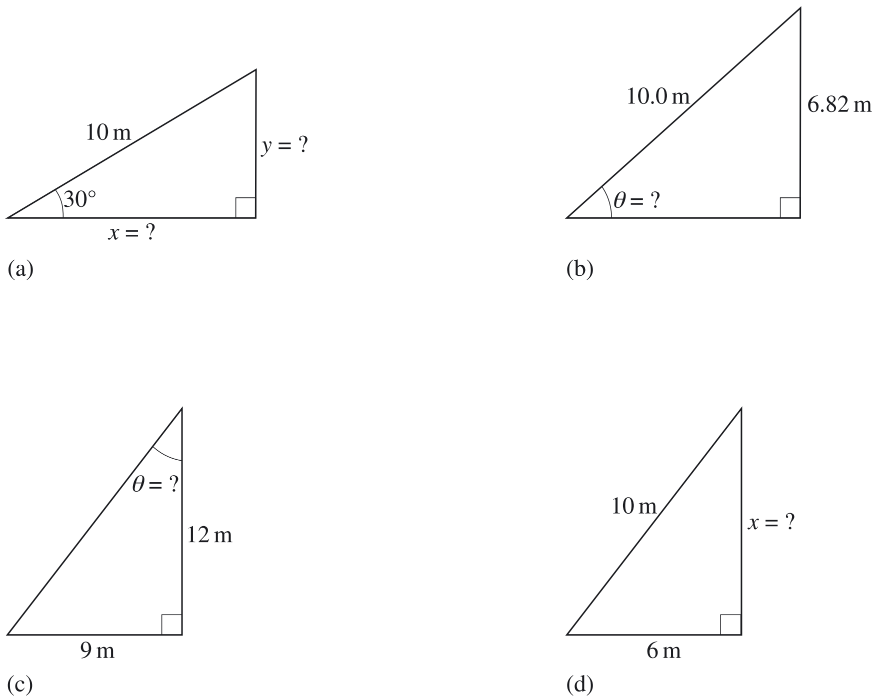


Figure 1 For use with SAQ 9.

3.4 Graphs

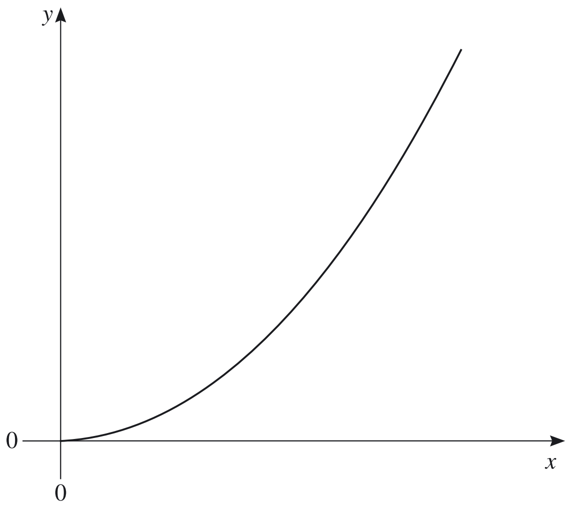
You should be able to read graphs and extract numerical information from graphs. You should also be able to interpret graphs in terms of the mathematical relationship between the variables plotted, and to understand a graph as a visual representation of a mathematical function (S151: Chapter 5).

SAQ 10

If you were told that $y \propto \frac{1}{x}$, would you expect a graph of y against x to be a straight line? Would it go through the origin? ■

SAQ 11

Look at the graph in Figure 2 below. Which of the mathematical functions (a) to (d) best describes this graph? ■



(a) $y = Ax$

(b) $y = Ax^2$

(c) $y = A/x^2$

(d) $y = Ae^x$

Figure 2 For use with SAQ 11.

Physics is frequently concerned with quantities that are *changing* — either as a function of time, or one quantity changing in response to another (e.g. volume of a gas changing with pressure). Thus the *rate of change* of a quantity is often of as much interest as the value of the quantity itself.

Speed, for example, is defined as the rate of change of position, and acceleration as the rate of change of speed.

When shown in graphical form, the rate of change of one quantity with respect to another can be interpreted as the **slope**, or **gradient**, of the graph.

You should be able to measure the gradient of a graph and use the value in calculations.

SAQ 12

The graph in Figure 3 below shows the distance s travelled by a vehicle against time t. Estimate the speed of the vehicle at time $t = 12$ s. ■

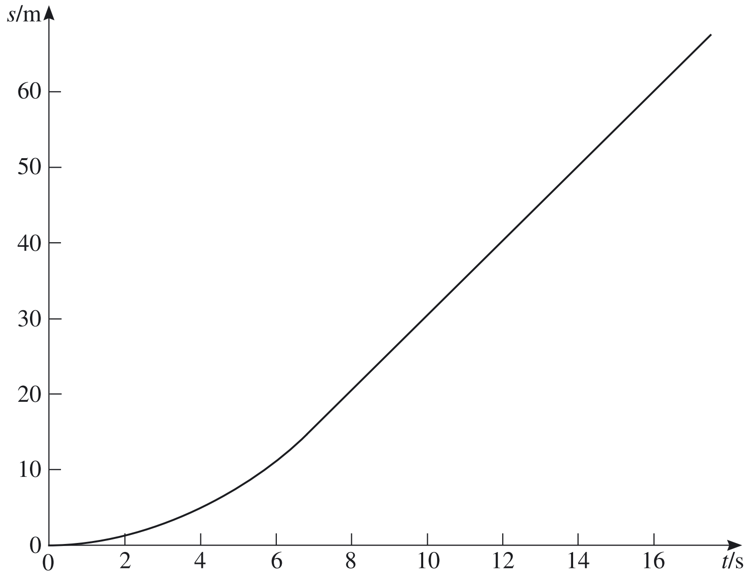


Figure 3 For use with SAQ 12.

3.5 Additional mathematical topics

S207 also introduces some additional mathematical topics that you may not have come across before: logarithms and exponentials (S151: Chapter 7), vectors, and differential calculus (S151: Chapter 10).

Logarithms and exponentials are used widely in S207. In particular, the phenomenon of **exponential decay** occurs in a lot of physical processes, including radioactivity, vibrations and waves, and in electronic circuits.

If $y = a^b$ then b is described as the **logarithm** of y to the base a. Logarithms may be taken using *any* number as the base. Sometimes it is convenient to take logarithms to base 10 (written as $\log_{10}$), although these days this is usually only done when plotting graphs.

In most mathematical work and calculations, logarithms are usually taken to base e (and written as $\log_e$ or as ln): the number e (= 2.718 28…) is known as the **base of natural logarithms**.

The process of raising e to a power (as in $y = e^x$) is known as **exponentiation** and the term e^x is known as an **exponential**.

Vectors are quantities in which **direction** is important, for example, force, velocity and acceleration. S207 is concerned extensively with situations where, for example, a force is applied in a direction *different* from the direction of motion. Vectors are essential for this type of calculation.

If you are familiar with navigation and map-reading or if you are good at visualizing objects in three dimensions, you may find this topic easier to pick up than if you find these things difficult.

Differential calculus is concerned with calculating rates of change of quantities using mathematical rather than graphical means. A large number of mathematical relationships of the form $y = f(x)$ (this means 'y is a function of x') can be analysed using the process of **differentiation** to find the rate of change of y with respect to x.

If you are confident with graphs, functions and algebra you may find this topic easier to pick up than if you find these things difficult.

All of these topics are taught from scratch within S207. However, the time available for their study is very limited, so if you have *never* encountered these subjects before, we would *strongly* advise you to study a Level 1 OU mathematics course prior to S207. The OU course S151 *Maths for Science* is available four times a year, and it is possible to study this course prior to starting S207. In any case, we highly recommend that you spend some time studying the S207 *Maths Handbook* before S207 gets underway.

4 Key concepts

The physics concepts needed for S207 are fully taught within the course, so no prior knowledge of physics is *required*. For this reason there are no questions attached to this section.

However, some familiarity with basic physics concepts would be helpful for the early parts of the course. In the following sections we outline some of the more basic of the physics concepts that will be introduced in S207.

4.1 Basic mechanics

Here we look at **Newton's laws**.

Newton's first law states that an object will remain at rest, or continue to move in a straight line at constant speed, unless acted on by an external **force**.

Newton's second law states that the magnitude of an unbalanced force, F, on an object is equal to the mass m of the object, multiplied by its acceleration, a. The direction of the acceleration is the same as the direction of the unbalanced force.

In symbols, this is expressed as $F = ma$. The SI unit of force is the **newton** (N).

Force is therefore measured in **newtons**: $1\,\mathrm{N} = 1\,\mathrm{kg\,m\,s^{-2}}$.

Newton's third law states that, when two objects interact, the force exerted by the first object on the second is equal in magnitude and opposite in direction to the force exerted by the second object on the first.

Newton's law of gravitation states that two particles of mass m_1 and m_2, separated by a distance r, attract each other with a gravitational force (F_g) that is *proportional* to the product of their masses (i.e. $m_1 \times m_2$, usually written m_1m_2). However, this force is *inversely proportional* to the square of their separation (i.e. r^2). In this case, the constant of proportionality is the gravitational constant, G.

The above law can thus be expressed as:

$$F_g = \frac{Gm_1m_2}{r^2}.$$

4.2 Energy

Energy exists in a number of different forms. It can be converted from one form into another and transferred from one object to another or from one location to another. The SI unit of energy is the **joule** (J): $1\ \text{J} = 1\ \text{kg m}^2\ \text{s}^{-2}$.

The **law of conservation of energy** states that the total amount of energy in an isolated system (i.e. a system that is not acted upon by an outside agent) is constant, since energy can neither be created nor destroyed.

Power, P, is the rate at which energy E is converted or transferred in time t, and is given by the expression $P = \Delta E/\Delta t$ where ΔE is the energy output in time Δt. The SI unit of power is the **watt** (W): $1\ \text{W} = 1\ \text{J s}^{-1}$.

4.3 Light

Light is a form of **electromagnetic radiation**. Light forms a narrow band of visible radiation within the much broader **electromagnetic spectrum**. Different colours of light correspond to different **wavelengths** of this electromagnetic radiation, with red light corresponding to a longer wavelength, and blue light to a shorter wavelength.

Outside the visible range there are many other forms of electromagnetic radiation. At progressively longer wavelengths we have first **infrared**, then **microwaves** and then **radio waves**. At wavelengths shorter than the visible range we have first **ultraviolet**, then **X-rays** and finally **gamma rays**.

In a vacuum, light travels at a constant speed c ($= 3 \times 10^8\ \text{m s}^{-1}$) and the frequency f of the electromagnetic wave is related to the wavelength λ by $c = f\lambda$.

When interacting with matter, light can also behave as if composed of particles. These particles are called **photons** and the energy E of each photon depends on the frequency f of the light: $E = hf$. Radio waves and microwaves are thus less energetic than visible light, whereas photons of X-rays and gamma rays have a much higher energy.

4.4 Electricity

Electrical currents are caused by movement of **charged particles** (usually **electrons**). Metals such as copper make good **conductors** of electricity because they contain electrons that are free to move. In **insulators** such as plastic, electrons are not free to move so electric currents cannot flow.

4.5 Structure of matter

All normal matter is composed of **atoms**. There are just over 100 different types of atoms (the **elements**) and each type has its own unique chemical properties.

Atoms themselves are composed of electrons surrounding a nucleus which is made up of **protons** and **neutrons**. Atoms of each particular element are distinguished by the number of positively charged protons in the nucleus (and the equal number of negatively charged electrons). For example, the sodium atom has a nucleus containing 11 protons (and 12 neutrons) surrounded by 11 electrons.

An **atom** of a particular element consists of:

- a **nucleus** containing Z **protons** (Z is the atomic number) plus a variable number of neutrons (N is the number of neutrons), thus giving a range of

isotopes of the element with mass number $A = Z + N$, (the value of Z defines a particular chemical element); and

- a cloud of **electrons** that surrounds the nucleus, containing Z electrons in electrically neutral atoms.

The three normal phases (or states) of matter are **solid**, **liquid** and **gas**. Most substances can exist in any of these phases, depending on the temperature and the pressure to which they are exposed.

5 Other skills

5.1 Study skills

You will find it useful to have acquired the following skills:

Basic study skills: organize time and a suitable place for study, with space for books, paper, etc. and comfortable seating. Ability to pace study and to read effectively to identify relevant information and data from scientific texts and accounts.

Presentation skills: the ability to write coherently, present arguments in a logical sequence and write a scientific account with appropriate diagrams.

Problem-solving skills: a fully fledged method of solving physics problems is developed during the course, but you should already be familiar with the basic principles of: defining the problem, gathering and organizing information, developing a plan, selecting the correct tools (such as equations), and working methodically towards an objective.

5.2 Experimental work

S207 itself requires you to carry out little or no experimental work directly. However, physics has an important experimental aspect to it, so some familiarity with the basic principles and methods of experimental investigation would be useful.

For further development of experimental skills we would strongly recommend you to consider taking the residential course SXR207 *Physics by experiment* during the *same year* as studying S207. It is neither necessary nor recommended to take SXR207 *before* starting S207.

5.3 Computer skills

S207 contains a number of DVD-ROM based computer activities. There is a selection of interactive tutorials to accompany each Book.

Whilst no previous experience of computers is assumed and support is available for these computer-based activities, it would nevertheless be advantageous to have the following computer skills:

- basic mouse and keyboard skills.
- familiarity with basic Windows operations such as scrolling, menus, dialogue boxes, etc.

6 Further reading

The Sciences Good Study Guide, by A. Northedge, J. Thomas, A. Lane and A. Peasgood, Open University 1997 (ISBN 0 7492 3411 3).

S104, Exploring Science, Open University Level 1 Science course.

S151, Maths for Science, Open University 10 pt Level 1 Science course.

Basic Mathematics for the Physical Sciences by R. Lambourne and M. Tinker, published by John Wiley & Sons Ltd in collaboration with The Open University (ISBN 0 471 85207 4).

Countdown to Mathematics (Volume 1) by L. Graham and D. Sargent. Addison Wesley Longman, 1981 (ISBN 0 201 13730 5)

Countdown to Mathematics (Volume 2) by L. Graham and D. Sargent. Addison Wesley Longman, 1981 (ISBN 0 201 13731 3)

The S207 *Maths Handbook* will give you an idea of the level of mathematics used in the course. You can obtain a copy of the *Maths Handbook* by sending an A4 stamped addressed envelope to: S207 Course Manager, Physics and Astronomy Department, The Open University, Walton Hall, Milton Keynes, MK7 6AA.

7 Answers to self-assessment questions

SAQ 1

(a) $200\,000\,000 = 2 \times 10^8$

(b) $95 \times 10^5 = 9.5 \times 10^6$

(c) $1/1000\,000 = 1 \times 10^{-6}$

(d) $21\,000 = 2.1 \times 10^4$

(e) $0.63 \times 10^4 = 6.3 \times 10^3$

(f) $0.000\,33 = 3.3 \times 10^{-4}$.

SAQ 2

(a) $0.63\text{ m} + 2.218\text{ m} = 2.85\text{ m}$

(b) $8.4\text{ kg} - 3.02\text{ kg} = 5.4\text{ kg}$

(c) $(2.394 \times 10^3)\text{ m} \times (5.60 \times 10^4)\text{ m} = (1.34 \times 10^8)\text{ m}^2$

(d) $(7.642 \times 10^3)\text{ kg}/2.82\text{ m}^3 = 2.71 \times 10^3\text{ kg m}^{-3}$.

SAQ 3

$a = (v - u)/t$,

so $v - u = at$,

and $v = u + at$.

SAQ 4

$x = 2z^2/a$ and $a = 4zr$,

so $x = 2z^2/4zr$

or $x = z/2r$.

SAQ 5

$3.2^2 = 10$ (2 s.f.)

$17.4^2 = 303$ (3 s.f.)

$8.3^2 = 69$ (2 s.f.)

$0.5^2 = 0.3$ (1 s.f.).

Also $\sqrt{80} = 8.9$ (2 s.f.),

$\sqrt{111} = 10.5$ (3 s.f.),

$\sqrt{1015.3} = 31.864$ (5 s.f.)

$\sqrt{0.5} = 0.7$ (1 s.f.).

SAQ 6

(a) $\dfrac{x^5 \times x^2}{x^3} = x^4$

(b) $10^{-7} \times 10^5 = 10^{-2}$

(c) $y^{-3} \times (y^4/y^2) = y^{-1}$

(d) $z^{1/2} \times z^2 = z^{5/2}$.

SAQ 7

$y = kx^2$, $y = k/x^2$.

SAQ 8

(a) $\sin 60° = 0.87$

(b) $\cos 60° = 0.50$

(c) $\cos 30° = 0.87$

(d) $\cos 145° = -0.82$.

SAQ 9

(a) $x = 8.7$ m; $y = 5.0$ m

(b) $\theta = 43.0°$

(c) $\theta = 37°$

(d) $x = 8$ m.

SAQ 10

Since $y \propto \dfrac{1}{x}$, a graph of y against x would *not* be a straight line. (Note, however, that a graph of y against $\dfrac{1}{x}$ *would* be a straight line.) A graph of y against x would not go through the origin: $y = \infty$ when $x = 0$. (A graph of y against $\dfrac{1}{x}$ would go through the origin: $y = 0$ when $\dfrac{1}{x} = 0$.)

SAQ 11

The correct answer is (b): $y = Ax^2$.

(a) $y = Ax$ would give a straight-line graph passing through the origin.

(c) $y = A/x^2$ would give a graph that curved the opposite way and did not pass through the origin.

(d) $y = Ae^x$ would give a graph that curved upwards, but would not pass through the origin (since, when $x = 0$, $y = Ae^0 = A$).

SAQ 12

At time t = 12 s the speed of the vehicle is constant (since the graph is a straight line at this point). The speed is given by the gradient of the graph which is about 40 m / 8 s = 5 m s^{-1}.